Chapter 4
ANALYSIS AND ISSUE IDENTIFICATION

ANALYTICAL TOOLS

As part of the water supply planning process, it was necessary to develop several analytical tools to help identify potential issues and to provide insights on possible solutions. There are several tools available to assist in these types of analyses. In this planning effort, the ground water flow model MODFLOW was selected to assist in evaluating the reaction of the Floridan Aquifer System (FAS) under the projected increased use. Three MODFLOW models were used to cover different parts of the Kissimmee Basin (KB) Planning Area. These models were used in conjunction with a Geographic Information System (GIS) and other mapping techniques to project areas where possible adverse impacts might occur. Also completed as part of this planning effort was an analysis of the surface water system for the Lake Istokpoga-Indian Prairie Basin. In this evaluation, water budget and statistical models were utilized to assess the availability of surface water supplies for that region.

The following sections in this chapter provide the results of the modeling efforts employed to identify the potential problems projected for the 2020 water use. This chapter also provides information regarding other analytical techniques that were applied to assess the effect of the predicted aquifer response to the resource protection criteria identified by the advisory committee.

CHAPTER 373 RESOURCE PROTECTION TOOLS AND LEVEL OF CERTAINTY

It is important to have an understanding of the relationship between the different levels of harm specified in the statutes and the various District programs that operate to protect the resources. One goal of Chapter 373 is to ensure the sustainability of water resources of the state (Section 373.016, F.S.). This chapter provides the District with several tools, with varying levels of resource protection standards. Protection programs include the District's surface water management and consumptive use permitting regulatory programs, Minimum Flows and Levels (MFLs), reservations of water and the District's Water Shortage Program. The role of each of these and the protection that they offer, are discussed in the following section.

Sustainability is the umbrella of water resource protection standards (Section 373.016, F.S.). Each water resource protection standard must fit into a statutory niche to achieve this overall goal. Pursuant to Parts II and IV of Chapter 373, surface water management and consumptive use permitting regulatory programs must prevent **harm** to the water resource. Whereas water shortage statutes dictate that permitted water supplies must be restricted from use to prevent **serious harm** to the water resources. Other protection tools include reservation of water for fish and wildlife, or health and safety

(Section 373.223(3)), and aquifer zoning to prevent undesirable uses of the ground water (Section 373.036). By contrast, MFLs are set at the point at which **significant harm** to the water resources, or ecology, would occur. The levels of harm cited above, harm, significant harm, and serious harm, are relative resource protection terms, each playing a role in the ultimate goal of achieving a sustainable water resource.

Level of Certainty

Certainty that sufficient water supplies will be available to water users and the environment is provided by varying tools. Level of certainty is the level of assurance provided to consumptive users and the environment that water will be available to meet reasonable demands to specific hydrologic conditions. The level of certainty evaluated in the planning process defines the availability of water to reasonable beneficial uses *and* the level of protection afforded to the water resources. The following resource protection framework in **Figure 4** is discussed in terms of the level of certainty and the varying tools available under Chapter 373 to protect water resources.

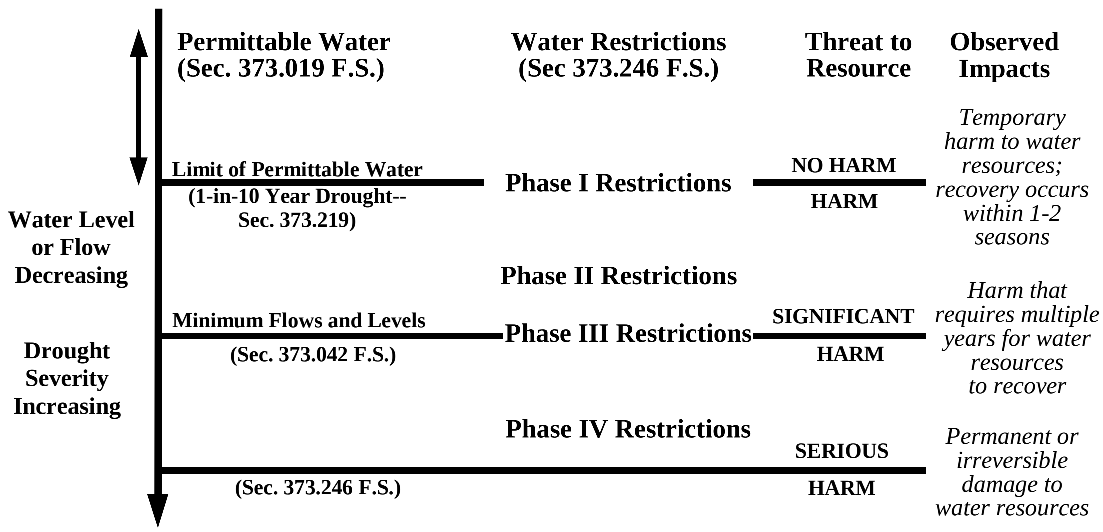

Figure 4. Conceptual Relationship among the Terms, Harm, Significant Harm, and Serious Harm.

Water Supply Planning Process and Level of Certainty

Fundamental to the water supply planning process is the quantification of existing and projected demands under a level of certainty. The 1997 Water Supply Legislation (CS/ HB 715, et al.), requires the water management districts to provide as a part of the regional water supply plan:

> [a] quantification of the water supply needs for all existing and reasonably projected future uses within the planning horizon. The *level-of-certainty* planning goal associated with identifying the water supply needs of existing and future

> reasonable-beneficial uses shall be based upon meeting those needs for a 1-in-10 year drought event.

These demands are evaluated by water availability assessment tools (ground water/surface water models) to estimate the potential impacts of the associated cumulative use. In this evaluation process, certain assumptions/constraints are defined to protect the water resources from over development. These constraints identify where in the KB Planning Area threats, such as saltwater intrusion, wetland stress, pollution or others, to the water resources could potentially occur.

Another implication of the level of certainty in water supply planning is that it defines where water resource development and water supply development projects need to be implemented to meet the projected demands for the appropriate level of certainty (Section 373.0361, F.S.). Once the water supply plan is completed and the water resource development and water supply development projects are defined which assure all reasonable demands will be met, the regulatory process becomes one of several plan implementation tools.

Consumptive Use Permitting Link to Level of Certainty

Under Section 373.219, F.S., the yield of the source, or amount of water which can be permitted for use, is limited by the resource protection criteria which defines when "harm" will occur to the resource. Resource protection criteria have been adopted by the water management districts under the three-prong test referred to in Section 373.223, F.S., and particularly the reasonable-beneficial use test. Such criteria are aimed at preventing saltwater intrusion and upconing, harm to wetlands and other surface waters, aquifer mining and pollution.

Section 373.219 also recommends that harm be considered the point at which adverse impacts to water resources that occur during dry conditions are sufficiently severe that they cannot be restored within a period of one to two years of average rainfall conditions. These short-term adverse impacts are also addressed under the CUP Program, which calculates allocations to meet demands up to the appropriate level of certainty.

Water Shortage Link and Level of Certainty

By basing resource protection criteria on a specific uniform level of certainty, it is possible to predict when water uses may be restricted by water shortage declaration. In a drought more severe than the drought event associated with the level of certainty, consumptive users no longer have the assurances that water will be available for use in their permitted quantities. During these drought conditions, both consumptive users and the water resources will experience a shared adversity.

Pursuant to Section 373.246, F.S., water shortage declarations are designed to prevent serious harm from occurring to water resources. Serious harm, the ultimate harm to the water resources that was contemplated under Chapter 373, F.S., can be interpreted as long-term, irreversible, or permanent impacts. The water shortage trigger levels are tools used to "trigger" imposition of water shortage restrictions based on climatic events, continued decline in water levels and a need to curtail human demand to correspond to decreasing supplies. Each level corresponds to a level of water shortage restriction. These restrictions act to apportion among uses, including the environment, a shared adversity resulting from a drought event. Adoption of the resource protection criteria as water shortage trigger indicators also serves the purpose of notifying users of the risks of water shortage restrictions and potential for loss associated with these restrictions.

Minimum Flow and Level Link to Level of Certainty

Minimum flows and levels are the point at which further withdrawals would cause significant harm to the water resources. Significant harm is recommended to be defined as a loss of specific water resource functions that take multiple years to recover, which result from a change in surface water or ground water hydrology. According to the resource protection framework above, this level of harm requires that consumptive uses be cutback heavily, imposing the potential for economic losses, to prevent significant harm and serious harm. This shared adversity between the environment and water users is implemented through the water shortage program discussed above.

Section 373.0421, F.S. requires that once the MFL technical criteria have been established, the District must develop a recovery and prevention strategy for those water bodies that are expected to exceed the proposed criteria. It is possible that the proposed MFL criteria cannot be achieved immediately because of the lack of adequate regional storage and/or ineffective water distribution infrastructure. These storage and infrastructure shortfalls will be resolved through water resource development and water supply development projects, construction of facilities and improved operational strategies that will increase the region's storage capacity and improve the existing delivery system. Planning and regulatory efforts will, therefore, include a programmed recovery process that will be implemented over time to improve water supply and distribution to protect water resources and functions. Development of a MFL recovery and prevention plan for the water resource will be incorporated into the regional water supply planning process to ensure consistency for those areas where harm has been identified.

GROUND WATER ANALYSIS

In an effort to assess the ground water conditions within the planning basin, three ground water models were used. Two of the models were developed by the SFWMD, and include the Osceola County model and the Glades, Okeechobee, Highlands (GOH) County model. The third model used in the evaluation, the Orlando Metropolitan model, was developed by the USGS in conjunction with the SFWMD and SJRWMD. This latter model focuses on the Orlando metropolitan area in Orange and Seminole counties. The spatial relationship of these three models is shown in **Figure 5**.

Each of the models developed used historical information as a means of calibrating the models. The year 1995 was identified as a base year for making predictions of potential Floridan aquifer water level changes resulting from water use during a 1-in-10

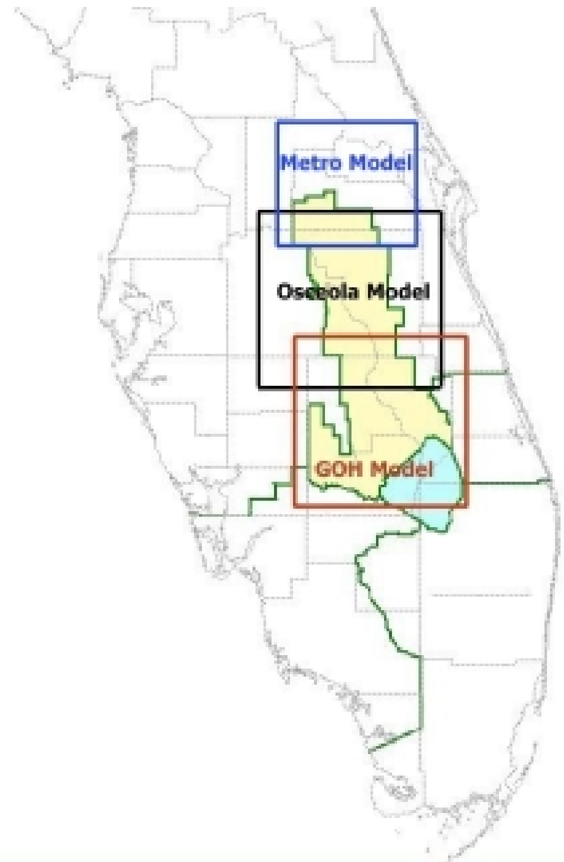

Figure 5. Location of Model Domains.

drought under a year 2020 water use pattern. Each of the models contains multiple layers, representing the various aquifers found in the planning region. The Osceola and GOH models concentrated on predicting the reaction of the Upper Floridan aquifer to the proposed 2020 water use stresses. In these two models, the surrounding aquifers, although active, were not the primary focus of the modeling effort. Therefore, the results pertaining to the aquifers other than the Upper Floridan aquifer are considered less reliable. The model layers representing the surficial aquifer in all three models were not active. Chapter 10 of the Support Document provides a discussion of the modeling assumptions and how each affects the modeling results. Appendix H describes the details on the construction and calibration of the modeling tools.

In addition to the use of these three models, efforts were made to compare the results of these models with the modeling efforts being made by the SJRWMD and SWFWMD where their respective work overlapped portions of the planning basin. The SJRWMD's model, the East Central Florida Regional Ground Water Flow model, encompasses all or portions of Lake, Orange, Osceola, Seminole, and Polk counties. The SWFWMD, in conjunction with the USGS, developed the Lake Wales Ridge model covering portions of Osceola, Polk, Hardee, Highlands, and Desoto counties. Results generated as part of the SFWMD analysis were compared to the results of these two models to assure similarity of results.

Results of the modeling analysis for the Upper Floridan aquifer are shown in **Figures 6** and **7**. **Figure 6** shows the anticipated change in water level between 1995 and 2020 for average water use conditions. **Figure 7** shows the predicted change in water level from 1995 to 2020 for the Upper Floridan aquifer with demands predicted for a 1-in-10-drought condition. These contours represent the impacts due to increases in withdrawals occurring within the SFWMD. For those areas within the SJRWMD that are covered by the model domain, the 2020 projections for that district were included in the simulations. These additional withdrawal amounts represent only a few percent in the total projected basin and is thought to have only minimal impact on the results of the model. The 1-in-10 drought definition used in this plan assumes a 1-in-10 drought rainfall condition preceded by an average rainfall year. The results of both of these climatic conditions are presented to illustrate that the anticipated change in Upper Floridan aquifer water levels from 1995 to 2020 are expected to be greater than the average condition presented in **Figure 6**, but less than steady-state drought conditions represented in **Figure 7**.

Results of the analysis indicate that Central Florida may experience between 10 and 15 feet of additional drawdown in the Upper Floridan aquifer in portions of southern Orange and northern Osceola counties under water use patterns projected for the year 2020. This change in predicted water levels is a result of the cumulative withdrawals of users located in the SFWMD portion of Orange and Osceola counties, and in particular, growth projected for those portions of the counties where the greatest amount of drawdown is projected to occur. The amount of drawdown is shown to decrease radially outward, extending into portions of Lake, northern Polk, and Brevard counties. Recharge occurring in western Orange, Lake, and Polk counties appears to be minimizing the extent to which the effects of drawdown extend further westward into the SWFMWD. It is likely that the simulated drawdown would be greater if the projected withdrawals from the SJRWMD and SWFWMD, located just outside of the modeled areas, were also included in this analysis.

The change in water levels projected for the lower portion of the basin, in parts of Glades, Okeechobee, and Highlands counties, is shown to be less than that predicted for the northern portion of the basin. This is due in part to the smaller amount of projected use of the Floridan aquifer in these counties, and in part, due to the hydraulic characteristics of the aquifer found in this area that work to limit the radial extent of the individual's projected drawdown. The model simulations for this area indicate that as much as 15 feet of drawdown may occur, however, the drawdown is believed to be associated with individual withdrawals and to a much lesser extent a cumulative effect. This gives a pattern of a series of isolated drawdown cones as seen in **Figure 6** and **7** for portions of Highlands and Glades counties.

RESOURCE PROTECTION CRITERIA

The resource protection criteria identify limits where further water use may cause harm to the resources. As part of the planning process, the advisory committee helped identify three limiting resource criteria: natural systems, water quality and land subsidence. The natural systems criteria included specific limits to protect wetlands, lakes

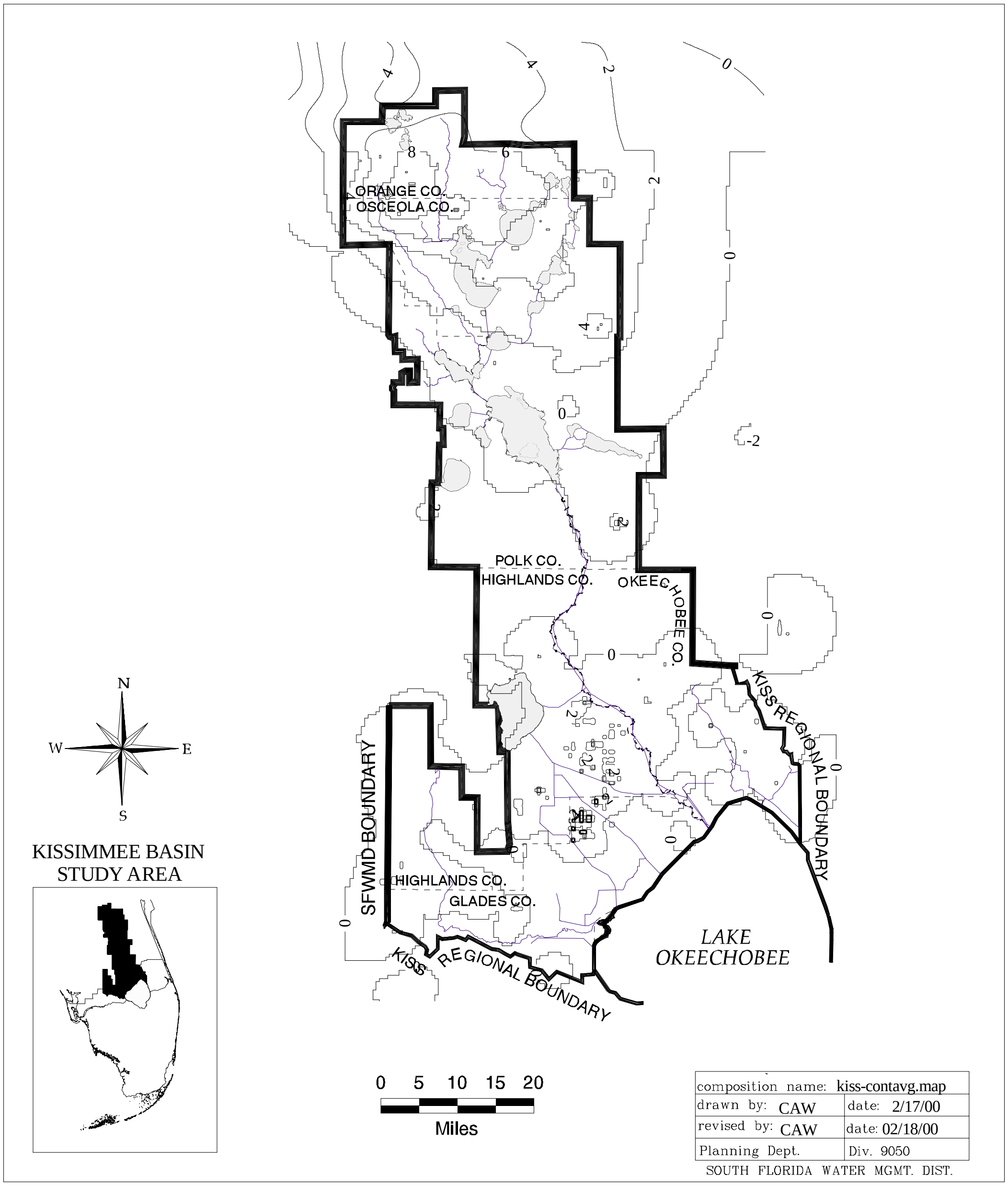

Figure 6. Change in Water Level in the Upper Floridan Aquifer for Average Conditions, 1995 to 2020.

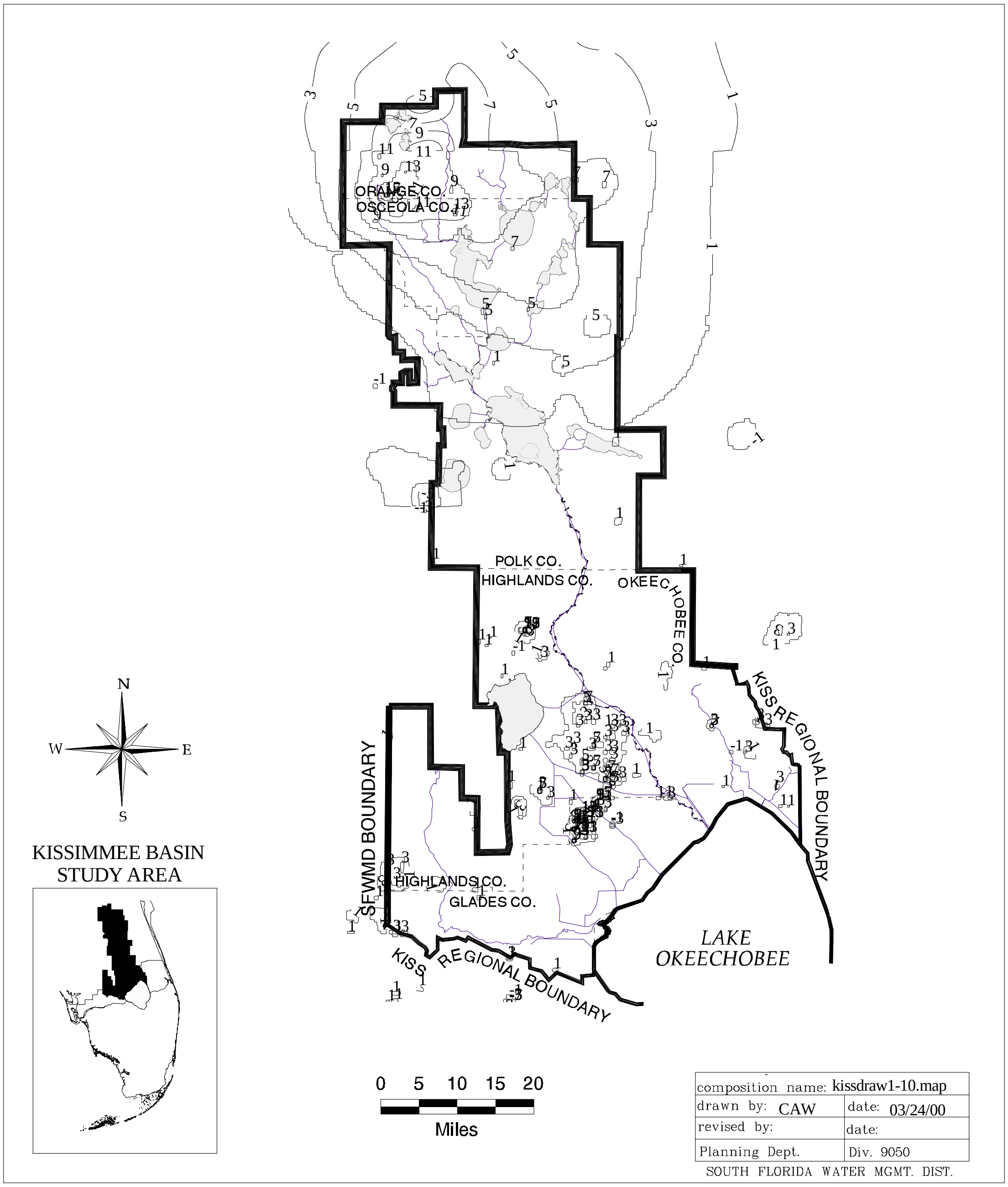

Figure 7. Change in Water Level in the Upper Floridan Aquifer during the 1-10 Drought, 1995 to 2020.

along Lake Wales Ridge, and spring flows in Orange County. Water quality was identified as a concern over the possible migration of poor quality water within the Floridan aquifer. Land subsidence is the last protection criterion identified and specifically addresses the formation of sinkholes as a result of water level changes. The following sections discuss each of these limiting criteria.

Wetland Protection Criterion

The District's Basis of Review (BOR) for Water Use Permit Applications requires that withdrawals of water must not cause harm to environmental features sensitive to magnitude, seasonal timing, and duration of inundation. Maintaining appropriate wetland hydrology (water levels and hydroperiod) is scientifically accepted as the single most critical factor in maintaining a viable wetland ecosystem (Duever, 1988; Mitch and Gosselink, 1986; Erwin, 1991). Water use inducing drawdowns under wetlands may potentially affect water levels, hydroperiod, and the aerial extent of the wetlands. The guideline currently used for Consumptive Use Permitting (CUP) states that harm to the wetland environment occurs when ground water level changes in the surficial aquifer, after a withdrawal of the maximum recommended allocation for 90 days with no recharge, are greater than one foot at the edge of the wetlands.

The District began a research project in 1995 to support refinement of the wetland drawdown criterion. This project involves long-term monitoring of wellfields and wetland systems including systems located in the Disney Wilderness Preserve area located in the KB Planning Area. Three years of data collection and analysis have been conducted to determine the relationship between variations in hydrology and wetland functions. This information is being used to develop revised CUP criteria for wetlands. These revised criteria are expected to include modifications to the existing guidelines by including recognition of differing wetland community types and seasonal hydroperiod requirements (Shaw and Huffman, 2000). The District has initiated a rulemaking effort this year to adopt rules Districtwide to incorporate these factors into the CUP process.

The complex geology found in the Central Florida area and the current limited information to define certain key hydraulic criteria make a demonstration of compliance with the current BOR criteria difficult. The modeling completed under this planning effort is also limited in its ability to predict compliance with the proposed BOR criteria. Recognizing these analytical limitations, the planning criterion identifies those areas where the risk of wetland harm, due to Floridan aquifer withdrawals, is greatest. The KB Water Supply Plan wetland resource protection criterion is defined as:

> The avoidance of large changes in Floridan aquifer levels in areas where the potential connection between the Floridan aquifer and the surficial aquifer is greatest.

This criterion was evaluated as part of the vulnerability analysis, discussed later in this chapter. The analysis identifies areas with the highest potential of experiencing a reduction of water levels in the surficial aquifer that might result in harm to wetlands.

Lake Level Criterion

The lake level protection criterion was identified by the advisory committee to address concerns over declining lake levels primarily along the Lake Wales Ridge. These lakes lie west of the KB Planning Area and within the SWFWMD. Geologic conditions along the ridge are such that the hydraulic connection between some lakes and the underlying aquifers appears enhanced. The SWFWMD has identified 46 “stressed” lakes along the ridge that have been below their historical range of levels for several years. SWFWMD has investigated the conditions surrounding these lakes and believes that that one cause of the lowered levels has been a reduction of levels in the Floridan aquifer. The planning effort undertaken by the SWFWMD seeks to have little or no future lowering of the Floridan aquifer water levels until other remedial actions are taken. The lake level criterion as it applies to the lakes along the Lake Wales Ridge is identified as:

> Little or no lowering of Floridan water levels beneath the Lake Wales Ridge.

In addition to the issue of lakes along the Lake Wales Ridge, a concern was raised about the possible impacts to water levels of unregulated lakes located in the KB Planning Area. Most of the major lakes within the KB Planning Area are managed according to a regulation schedule established by the USACE. It is the presumption of this plan that the possible impacts from water use withdrawals to lake levels on lakes that have a regulation schedule would be minor compared to those changes resulting from the regulation schedule. This includes the operational levels for lakes like Lake Istokpoga. For this planning level effort, lake levels for non-regulated lakes were presumed to be equally sensitive to water level changes as wetlands and therefore are addressed under the wetland criteria and subsequent analysis. This presumption is conservative and is proposed to be addressed more thoroughly when MFLs have been established for the lakes on the District’s priority schedule.

Ground Water Quality Criterion

The significant movement of poorer quality water into fresh water zones of the Floridan aquifer represents a limit on the amount of ground water that can be withdrawn without causing harm to the resource. Significant saline water movement is defined in Section 3.4 of the District’s Basis of Review for Water Use Permit Applications (BOR) as the saline interface moving to a greater distance inland or vertically than has historically occurred or as a consequence of seasonal fluctuations and is detected by a sustained increase in dissolved chloride concentrations. For the purposes of this planning effort, chloride concentrations in the ground water were taken as the identifying water quality parameter upon which the poor quality zones were designated. The water quality protection criteria is therefore defined as:

> Movement of the saline water interface (250 mg/L chloride concentration isochlor) to a greater distance inland or vertically.

Spring Discharges Criterion

Although there are no natural springs located within the KB Planning Area, several critical springs are located in northern Orange County in an area called the Wekiva Basin. The SJRWMD has identified these springs as having critical environmental function and has set minimum flow values for eight of these springs. These minimum flow requirements are established in rule under Chapter 40C-8, F.A.C. These identified flow requirements are based upon the long- term average flow requirements from the springs to maintain the environmental function of wetland communities along this river and its tributaries. The spring discharge criterion is a requirement to:

Maintain the minimum flow requirements set forth in Chapter 40C-8. F.A.C.

Sinkhole Formation Criterion

Sinkholes are a common occurrence in certain portions of the state where unstable geologic and fluctuating hydrologic conditions work together to cause potentially dangerous forms of land subsidence. In certain instances, the conditions that lead to the formation of sinkholes can be enhanced if the hydrostatic head difference between the surficial and Floridan aquifers is significantly increased. Chapter 40E-2.301(b) and Section 3.6 of the BOR requires the District to prevent impacts to off-site land uses. The sinkhole criterion is intended to prevent off-site impacts of land use that might be adversely affected by land subsidence caused by a reduction in water levels. Although a relationship between aquifer drawdown in the Floridan aquifer and the rapid formation of sinkholes has been documented in areas where the overburden is relatively thin, the degree to which these two factors are related is less defined. An existing District guideline, applied through the CUP Program, limits Floridan aquifer drawdowns to five feet, measured one foot from the well head in areas identified as having a higher number of sinkholes. This guideline is based upon two studies, one completed by the USGS and another by the Florida Sinkhole Research Institute (University of Central Florida), which describes the soil conditions in Central Florida in relationship to the formation of sinkholes. These studies identify the factors involved in sinkhole development and the locations where the combination of geologic factors result in the most frequent development of a specified type of sinkhole.

Figure 8 is presented to show the relationship between the water level in the Floridan aquifer in southwest Orange County and the occurrence of documented sinkholes within Orange and Osceola counties for the past 23 years. A total of 88 sinkholes, spread throughout these counties, are documented for this time period. The graph shows that the highest frequency occurred during 1981 when water levels were an estimated 8 feet below the average level of 58 feet. In reverse, the lowest frequency occurs between 1992 and 1997 when water levels are generally higher. This evaluation focuses on determining if there is a relationship between the water level in the Floridan and the increases in sinkhole occurrence. Much like the previous studies sited, the quantification of a unit relationship could not be defined. A separate analysis showed that approximately 50 percent of the sinkholes occurred when water levels were below the average Floridan water level, while the remaining 50 percent occurred when levels were above the average level. Neither of these analyses conclusively demonstrates a connection between water level changes in the Floridan aquifer and the formation of sinkholes. The KBWSP criterion of sinkhole formation is described as:

> The avoidance of large changes in Floridan aquifer water levels in areas that have geologic conditions that have resulted in more frequent development of sinkholes.

The conclusion of this first portion of this evaluation is that additional studies are needed to clarify this relationship. These analyses also suggest that the five-foot guideline may be too restrictive and that a less prohibitive drawdown amount, applied to a limited geographic area would still be conservative, but adequate. For the purpose of this planning effort, ten feet of regional drawdown was selected as a reasonable compromise between following the current regulatory guideline and having no drawdown guideline at all. The technical basis for using a 10-foot guideline is limited and is based primarily upon professional judgement of the District geologists. Again, this analysis is designed to identify areas of potential concern and where further studies on the relationship between water levels and land subsidence could be focused.

ANALYSIS

Wetland Vulnerability Analysis

Ground water flow models developed for the KB Planning Area are steady-state in nature and have a “fixed” layer representing the surficial aquifer. These features limit the model’s utility in predicting drawdowns in the surficial aquifer, which in turn could be interpreted to indicate harm to wetlands. An alternative analysis was developed to provide insight into which areas are most vulnerable to wetlands being harmed as a result of Floridan aquifer withdrawals.

The wetland vulnerability analysis was an approach taken as an alternative to predicting a fixed drawdown criterion for a given wetland. This type of analysis approaches the issue of wetland harm by assessing those factors that influence the change in water levels within the aquifer controlling wetland water levels. These factors include: the ability of water to move vertically thought the intermediate (Miocene) confining layer, location of wetland features, and the change in potentiometric head within the upper FAS due to changes in water use from 1995 to 2020. This analysis was accomplished using a GIS overlay technique that combines these factors and identifies areas with the appropriate combination of conditions that identify the degree of vulnerability.

The technique used involves generating a series of digital, georeferenced maps with each map representing a separate factor used in the analysis. Each map is divided into a series of rectangular grids with each assigned a score based upon a weighting criterion. The scores were summed and averaged and displayed as resultant map. For the purpose of this planning effort, divisions of 0-5 feet, 5-10 feet, and greater than 10 feet of drawdown in the Floridan aquifer were selected as reasonable guidelines to assist in identifying

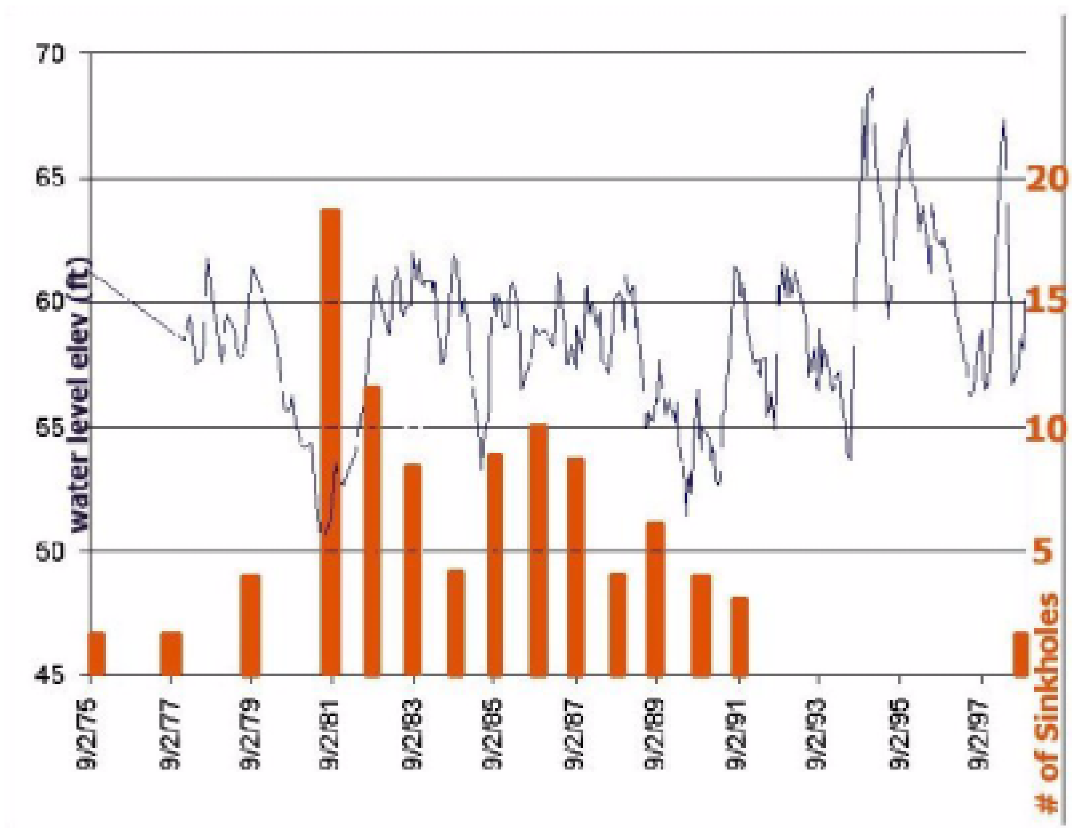

Figure 8. Water Level versus Occurrence of Sinkholes in Central Florida.

potential problem areas. The technical basis for using a 10-foot guideline is limited and is based primarily upon professional judgement of District geologists. An additional limitation of this analysis is the assumption of uniform vertical hydrologic conductivity throughout the basin. Appendix J provides a summary of this overlay process.

The results of the vulnerability analysis are shown in **Figure 9**. The darkest areas are areas where the combination of factors combine to create a region where water level changes in the surficial aquifer are most likely to occur within the KB Planning Area. Areas in medium gray tone are areas showing moderate risk, while areas in the lightest shade of gray show the least amount of risk for water level changes in the surficial aquifer due to Floridan withdrawals.

The purpose of this analysis was to identify areas most vulnerable to experiencing drawdown in the FAS translated to possible harm to wetland and non-regulated lake features. Areas in Southwest Orange and Northwest Osceola counties received the highest resultant score and are therefore identified as being the most vulnerable for lowering of the shallow aquifer as a result of the projected Floridan drawdowns from 1995 to 2020. This analysis identifies areas where, if harm to vegetation were to occur, the impact would most likely be first observed. Again, this analysis identifies areas where harm to wetlands is most likely to be observed, if it occurs. It also indicates where further studies on the relationship between water levels and possible wetland harm could be focused.

Lake Level Evaluation

The lake level protection criterion was identified to address concerns over declining lake levels primarily along the Lake Wales Ridge. These lakes lie west of the KB Planning Area and within the SWFWMD. The SWFWMD has identified 46 stressed lakes along the Lake Wales Ridge that have been below their historical levels for several years.

For the purposes of the planning effort, the lake level criterion was interpreted as drawdown of less than one foot at the boundary of the two districts. This one foot reflects a consideration of the level of predictive accuracy for the ground water models producing drawdown results in the Upper Floridan aquifer. A review of the projected Floridan aquifer drawdown along the western edge of the KB Planning Area (**Figure 10**) shows less than one foot of change in water level is projected beneath the ridge. This amount of predicted impact is considered minimal and is not expected to impede SWFMWD's efforts to restore the level of lakes along the ridge.

Ground Water Quality Evaluation

The movement of poorer quality water into freshwater zones of the Floridan aquifer was determined to represent a limit on the amount of ground water that could be withdrawn without causing harm. For the purposes of this planning effort, movement of the saline water interface (250 mg/L chloride concentration isochlor) inland or vertically was considered problematic.

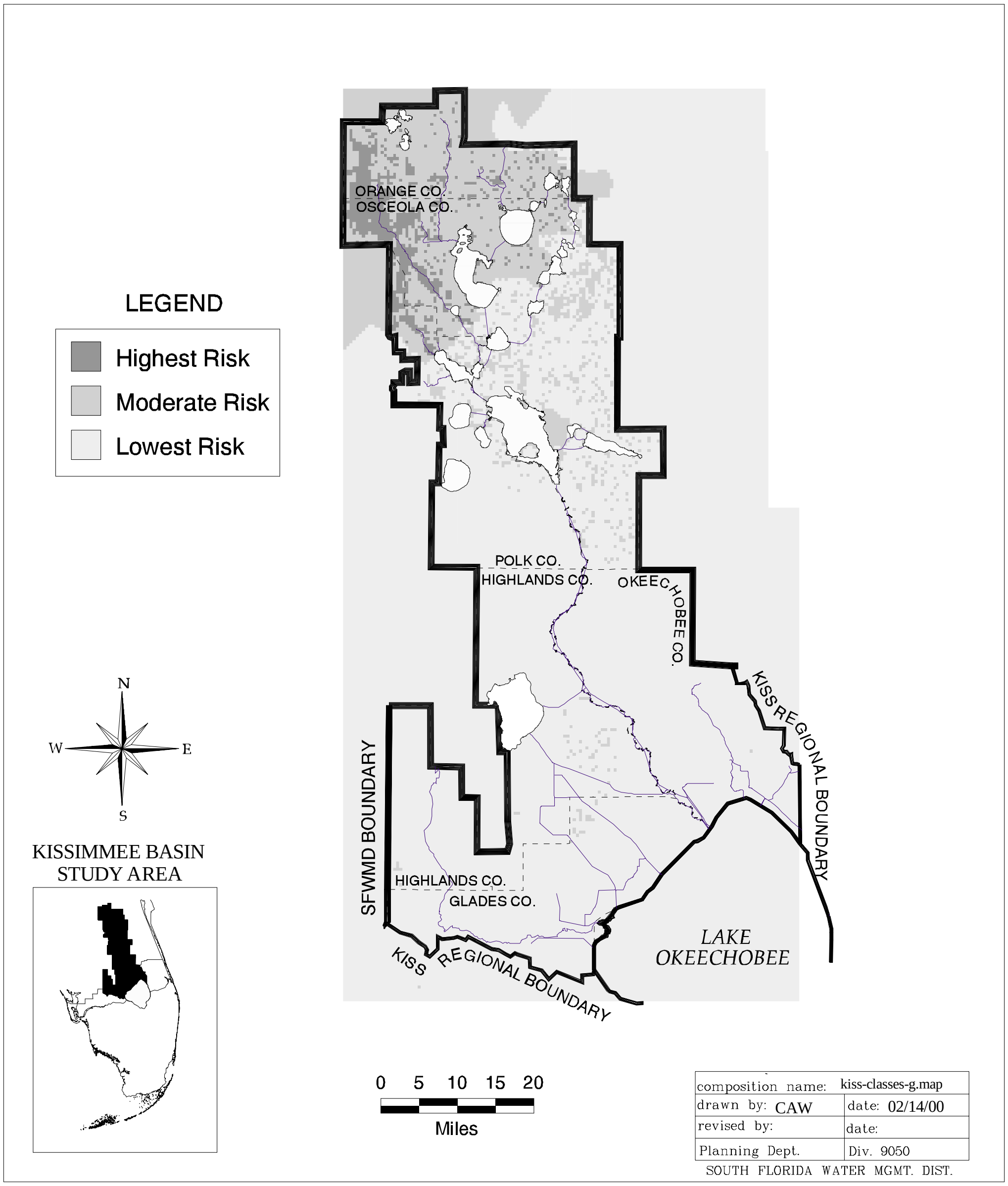

Figure 9. Location of Potential Wetland Impacts.

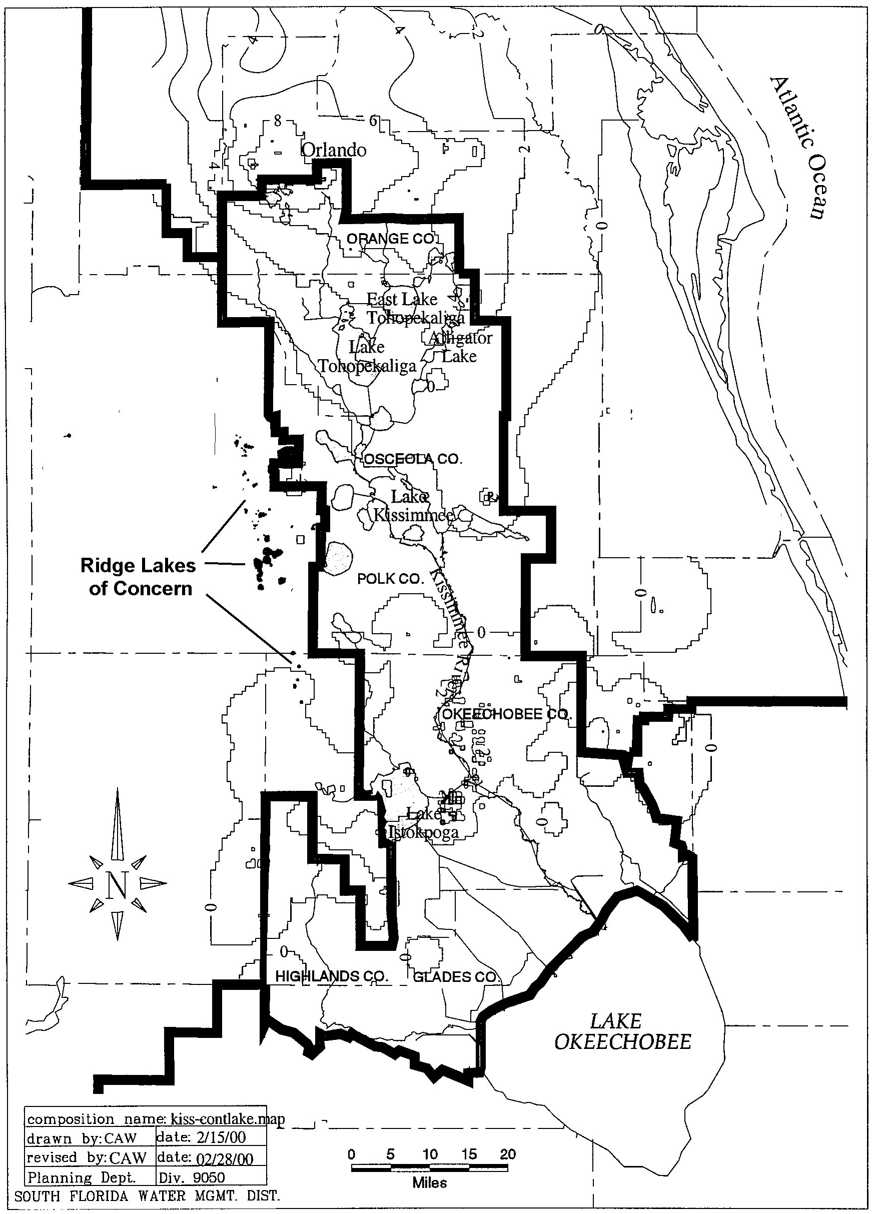

Figure 10. Location of Lakes along Lake Wales and Projected Floridan Drawdown.

The approach taken to address the movement of poorer quality water involved mapping the concentration of chloride levels within the upper FAS and comparing that information to the projected change in Floridan aquifer levels resulting from increased water use from 1995 and 2020 (1-in-10). The assumption of this analysis is that a lowering of hydrostatic heads adjacent to the location of the saline water interface will eventually cause the movement of poor quality water into existing freshwater zones. Areas identified as having greater than one foot of anticipated change in water level in the Upper Floridan aquifer, and where the chloride concentration in the Floridan is above 250 mg/L, were identified as areas of possible movement of the poor quality water. This one foot reflects a consideration of the level of predictive accuracy for the ground water models producing drawdown results in the Upper Floridan aquifer.

Results of this evaluation suggest that only the Cocoa Wellfield located in eastern Orange County will be as an area of concern. The city's wellfield is located near the existing saline/fresh water boundary. In addition, the easternmost wells of the Cocoa wellfield have historically had their withdrawals reduced due to increasing chloride concentrations. Future growth in Central Florida may worsen this condition. **Figure 11** shows the existing chloride concentration levels found within the Floridan aquifer for the KB Planning Area and the anticipated 1995 to 2020 drawdown. This analysis does not take into account other factors that may influence saline movement, which should be considered before a final determination of the actual movement of the interface is made.

Spring Discharge Evaluation

Although there are no natural springs located within the KB Planning Area, several critical springs are located in northern Orange County in an area called the Wekiva Basin. The SJRWMD has identified these springs as having critical environmental function and has set minimum flow values for eight of these springs. These minimum flow requirements are established in rule under Chapter 40C-8, F.A.C. These springs contribute to the baseflow of the Wekiva River and several of its tributaries. The estimated flow requirements are based upon the environmental demands of this river and its tributaries.

Spring discharges in northern Orange County were evaluated using the USGS Metro model. This model directly calculates spring discharges based upon changes in Floridan aquifer levels from 1995 to 2020. Unlike the other analyses presented in this plan, the USGS simulation evaluates the potential spring impact based upon the projected cumulative withdrawals from both the SFWMD and the SJRMWD portions occurring in Central Florida. This model, cooperatively developed with the SJRWMD and SFWMD, directly simulates spring discharges as a function of aquifer head levels.

The resultant 2020 spring discharges calculated by the model were compared to that set forth in Chapter 40C-8, F.A.C., to determine which might exceed the resource criteria. **Table 4** provides the results of the spring discharge estimates. The results represent the average of the wet and dry season runs made using the USGS model. The results of the model simulations show that five of the springs are anticipated to fall below

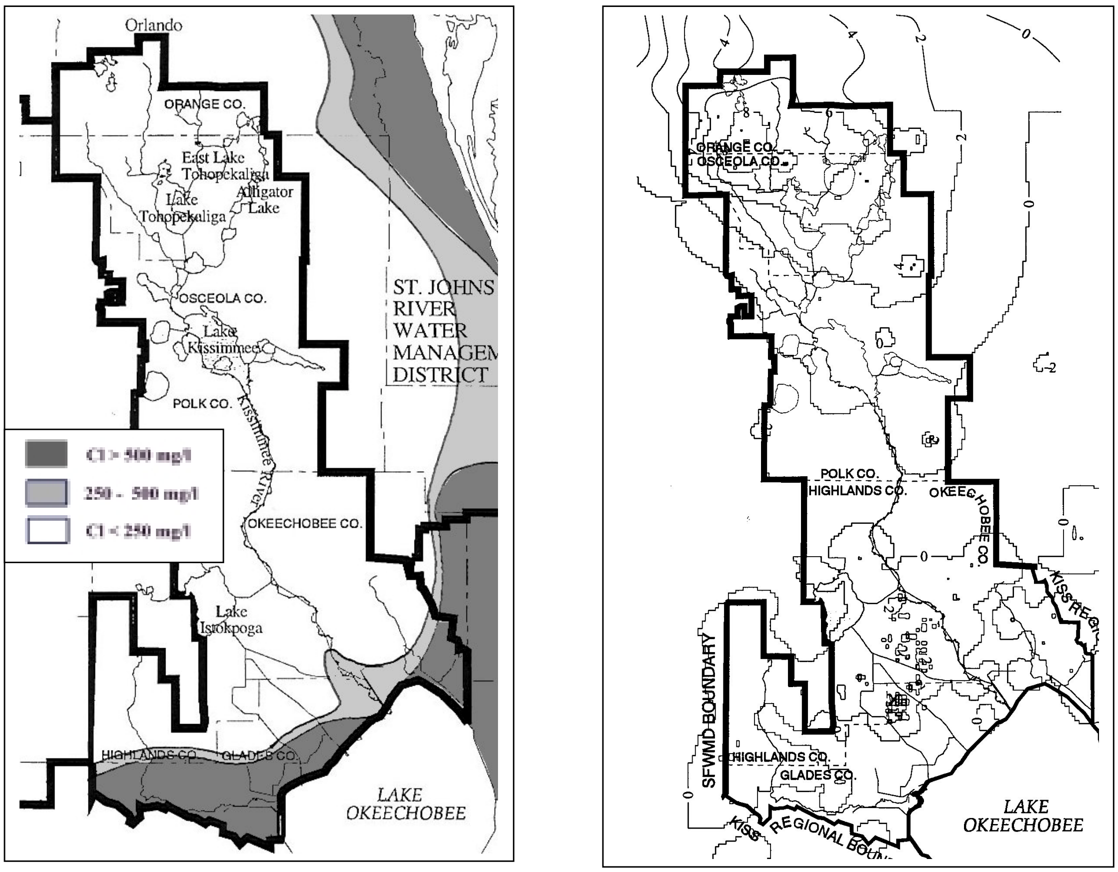

Figure 11. Location of Poor Quality Water and Projected Floridan Drawdown.

the required minimum flow amount set forth in 40C-8, F.A.C. These are the Wekiva, Rock, Sanlando/Palm/Starbuck, Miami, and Seminole springs.

Table 4. Simulated Spring Discharge (cubic feet per second).

Spring Name	Est. Pre-Dev. Discharge	Est. 1995 Discharge	Est. 2020 Discharge[a]	Min. Flow[b]	% Change
Wekiva	80	67.4	53.0	62	21
Rock	70	55.7	46.6	53	16
Sanlando/Palm/ Starbuck	50	39.0	18.6	35	53
Miami	6.5	4.7	3.3	4	29
Messant	20	15.5	13.8	12	11
Seminole	40	36.3	27.7	34	24

a. Average from wet and dry conditions.
b. As established in 40C-8; F.A.C.

Results presented in **Table 4** represent the reduction in average spring discharges due to the cumulative withdrawals occurring in both the SJRWMD and SFWMD portions of Central Florida. A separate analysis of the reduction in spring discharge due solely to withdrawals within the SFWMD was not completed as part of this planning effort. The conclusion of this evaluation is that the reduction of spring discharges is a concern that warrants further investigation. Prior to the determination on how best to address this issue, a separate analysis of the effects of ground water withdrawals in each respective water management district should and will be conducted.

Sinkhole Formation Evaluation

The sinkhole criteria is described as the avoidance of large changes in Floridan aquifer water levels that could encourage or trigger the formation of land subsidence. The analysis performed focuses on identifying areas with numerous previous sinkhole activity and projected large amounts of additional drawdown in the Floridan. For the purposes of this plan, areas were mapped that are projected to have the greatest amount of water level change (greater than 10 feet) and those areas that have been described by the USGS and Florida Sinkhole Research Institute as having the most suitable geologic conditions for sinkhole occurrence. These areas are identified as portions of Southwest Orange and Northwest Osceola counties are projected to be at increased risk.

SUMMARY OF GROUND WATER ANALYSIS

As part of the plan analysis, several ground water models were utilized. These models were used to simulate the projected change in water level in the Floridan aquifer from 1995 to 2020. Two simulations were made with these models, one representing the average 2020 demands and another representing the 2020 demands under a 1-in-10 drought condition. These simulations were both performed to give the reader an estimation of the projected range of drawdown between the two simulations. The difference between the two is about 3 to 4 feet in the area of greatest drawdown (southern Orange County and northern Osceola County) and less than 1 foot in Central Osceola County, based on demands in the SFWMD.

An evaluation was performed to determine which, if any, of the defined resource protection criteria are at most risk of being exceeded. The evaluation suggests that ground water use in areas south of the Osceola-Okeechobee county line are at least risk of causing harm to the resources over the next 20 years. The analyses for the areas north of this line show a significantly different picture. The analysis indicates that areas in Orange and Osceola counties are at an increased risk of showing harm to wetlands and lakes. In addition, there may be an increase in the risk for the formation of sinkholes in Southwest Orange and Northwest Osceola counties. The analysis also shows that the proposed water use may contribute to saltwater movement in eastern Orange County and the reduction of natural spring flows in northern Orange County. Lakes along the Lake Wales Ridge are projected to be unharmed from the withdrawals identified in this plan.

An effort was made to compare the results of the evaluations performed under this plan with evaluations made by the SJRWMD. The SJRWMD has made similar efforts to model the FAS in Central Florida. Although the results of the two modeling efforts are not directly comparable, the conclusions reached by each district parallel one another. Both planning efforts identified potential problems with harm to wetland, saltwater intrusion, and the reduction of spring flows in Central Florida.

The ground water related analyses performed as part of this planning effort are intended to provide a screening level look at the potential problems that may arise from future water use. This analysis is intended to provide insights into what problems may occur, where they may occur, and to provide a preliminary identification of options that may be warranted. A screening level approach was taken for the ground water evaluation because of the limitations on the accuracy of the models being developed and the ability to specify when harm occurs for each of the identified resource protection criteria. For this reason, many of the analyses completed identify the risks associated with future water use more than an estimation of the actual impacts. Results of these analyses are intended to provide guidance on the possible risks that may result from future ground water withdrawals and to identify where future research efforts should be focused.

SURFACE WATER ANALYSIS

The analysis of the surface water systems performed under this plan was limited to the Lake Istokpoga-Indian Prairie Basin. Many of lakes in the KB Planning Area are either directly controlled or influenced by lakes under a regulation schedule adopted by the U.S. Army Corps of Engineers and managed by the District. It was assumed under this plan that the potential impacts to these lakes as a result of ground water withdrawals would be small in comparison to the water level changes controlled through the annual lake level regulation schedules. Although a large direct withdrawal from one of these lakes could have potential impact, no such withdrawals were projected or requested. For these reasons, no analytic effort was made for these regulated lakes.

The discussions on the evaluation presented in this chapter focus on those analyses performed in evaluating the Lake Istokpoga-Indian Prairie Basin located northwest of Lake Okeechobee. In this evaluation, water budget and statistical models were utilized to assess the availability of supplies for the region.

Lake Istokpoga-Indian Prairie Basin Analysis

For the past decade, the use of additional surface water from the Lake Istokpoga-Indian Prairie Basin has been restricted as a result of several water shortages that occurred in the area during the 1980s. As part of the KBWSP planning effort, an evaluation of the water use problems of the Lake Istokpoga-Indian Prairie Basin and the preparation of recommendations regarding alternate water supply sources was completed. Under this analysis, the Lake Istokpoga-Indian Prairie Basin is defined as those areas that have access to the C-40, C-41, C-41A canals or Lake Istokpoga, either directly or via other canals.

The analysis evaluates water availability in the basin during a 1-in-10 drought condition. For purposes of this analysis, it was assumed that the drought was preceded by an average rainfall year and that the water level of Lake Istokpoga was at or near its average level at the end of the wet season in October.

A presumption in this analysis is that water currently released from the basin to either Lake Okeechobee or the Kissimmee River south of S-65D could be utilized as the first source in meeting the projected demands. As part of the analysis, the amount of discharge leaving the basin through water control structures S-68, S-71, S-72, and S-84 was quantified for the 1-in-10 drought condition. **Figure 12** shows the features of the Lake Istokpoga-Indian Prairie Basin and the location of these control structures. The second effort of the analysis was to determine if additional supplies could be released from Lake Istokpoga while maintaining the required minimum operational schedule and minimum canal levels set forth in the Water Shortage Rule 40E-22, F.A.C.

The analysis contains three major components, estimation of 1-in-10 water demands, determination of 1-in-10 drought discharges from the basin under the existing operation/management, and analysis of alternative sources. Water use estimates were determined using the methods described in Chapter 6 of the Support Document. All water use demands were calculated on a monthly basis using a statistically derived 1-in-10 drought condition. A description on how the 1-in-10 drought definition was determined can be found in Appendix B.

The analysis took two approaches to estimate the discharges from the control structures in the basin. These approaches included statistical and empirical methods. The statistical approach attempted to develop a mathematical correlation between rainfall patterns and releases from the control structures. The empirical approach reviewed 20

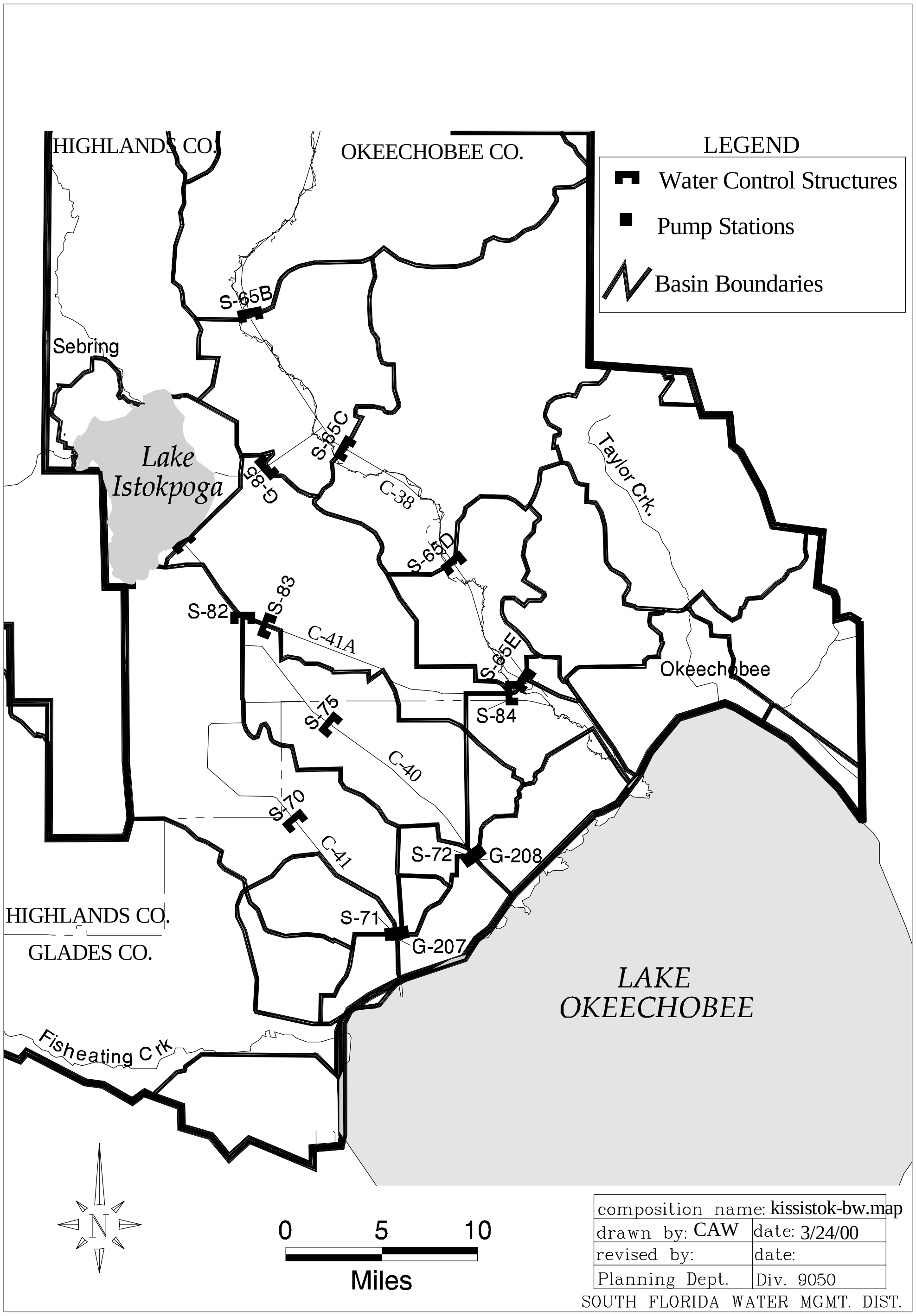

Figure 12. Features of Lake Istopoga/Indian Prairie Basin.

years of records to find years that matched the seasonal rainfall conditions of a 1-in-10 drought. The statistical approach was found to track the trends in discharge relatively well, but had less success in matching month to month values and the extreme discharge events. The statistical method is described in Appendix B. The results of this analysis were used only as a gauge for the results of the empirical method.

Under the empirical method, a search was made to find years within the period of record that were reasonably representative of a 1-in-10 drought condition. The analysis assumes that discharges from the lower three structures (S-71, S-72, and S-84) during these years are representative of the potentially available water during a drought year. The years of 1981, 1985, and 1996 were found to most closely represent the desired rainfall condition. The year 1981 and 1984 were preceded by drought years while 1996 was preceded by slightly wetter conditions. The method used to select these years is provided in Appendix I as an attachment to the water budget analysis. Although the three years selected reasonably represented 1-in-10 drought conditions on a seasonal basis and annually, each year had varying monthly total rainfall amounts. The flow data from these three years was averaged and used to generate synthetic monthly discharge estimates for the lower three structures. The synthetic discharge for the lower structures was created by taking the average annual discharge for the three selected years and distributing the volume monthly based upon the pattern of average year discharge for the same three structures. This was done to make the discharge information comparable to the generated water demands that were also based on a synthetic rainfall year. The synthetic monthly flows predicted for the lower three structures represent the water released and potentially available for use under the current operation/management of Lake Istokpoga and the Indian Prairie Basin structures. These discharge rates are shown in **Table 5**.

Once estimated, the projected synthetic flows were compared, on a monthly basis, to the estimated demand increases for the basin. The projected increase in demand is comprised of two components, the increased agricultural demands from 1995 to 2020, and the minimum discharge requirement as specified in Chapter 40E-22, F.A.C. The amount of water that is unmet by the current discharge from the basin during a 1-in-10 drought event is defined as the *deficit*.

A water budget model was created to address the use of additional sources of water to meet the remaining 2020 demand or deficit. These alternative sources include storage above Lake Istokpoga's minimum operation schedule and the delivery of water from Lake Okeechobee via existing or proposed pumps. **Table 5** shows the results of this analysis. The analysis indicates that use of the additional storage in Lake Istokpoga and the use of pumps on Lake Okeechobee can meet the projected deficit under the 1-in-10 drought condition. The demands presented in the table represent the projected increase in withdraws from 1995 to 2020. The results of the analysis presented in **Table 6** represents one example of a solution to meet the projected 2020 (1-in-10 drought) demands for the Indian Prairie Basin using a combination of additional water obtained from Lake Istokpoga and Lake Okeechobee. The analysis also presumes the 40E-22, F.A.C. minimum flow requirements will be removed through rulemaking. This example does not represent the only solution available using these two sources, but instead represents the solution that maximizes the use of Lake Okeechobee to meet the needs of new agricultural areas having access to canals C-40 and C-41 below the S-70 and S-75 structures. Mean water levels for the months of August and October are above the maximum regulatory schedule (line A) and indicate that releases for flood control may also be necessary during these months or could be stored as further reserves. Historical average monthly water levels for Lake Istokpoga can be found in Appendix I.

Table 5. Budget Demands Based on Capture of Existing Flow, Use of Istokpoga, and Use of Lake Okeechobee during 1-in-10 Drought Conditions.

Month	Demands & Min. Flow Req. (ac/ft)	Discharge to Lk Okeechobee (S-71,S-72, and S-84)	Min. Flow Req. 40E-22	Deficit[a] (ac/ft)	Additional Supply from Lk Istokpoga (ac/ft)	Pumping from Lk Okeechobee	Resulting Monthly Lk Istokpoga Stage (ft-MSL)
January	9,906	3,056	220	-6,630	2,188	4,442	39.22
February	11,737	3,209	650	-7,878	1,733	6,145	39.14
March	18,199	5,046	800	-12,353	2,718	9,635	38.92
April	12,858	2,771	540	-9,547	2,291	7,256	38.63
May	10,133	1,935	440	-7,759	1,707	6,052	38.04
June	24,785	12,157	6,500	-6,128	797	5,331	37.87
July	22,660	15,496	5,800	-1,364	546	818	38.12
August	20,964	23,763	5,500	8,300	0	0	38.60
September	26,958	16,893	6,100	-3,966	1,983	1,983	39.04
October	26,181	17,255	9,200	274	0	0	39.53
November	11,342	4,579	1,600	-5,164	1,033	4,131	39.52
December	9,140	4,632	360	-4,148	2,074	2,074	39.33
Total	204,865	110,791	37,710	-64,937	17,069	47,868	N/A

a. positive values indicates no deficit for that period.

The analysis performed does not address the issue of seasonal or annual drought events greater than the design event. In those instances, the availability of water to meet the entire growing season becomes more uncertain. Additional sources of back-up supply may be warranted during periods of greater than 1-in-10 year drought.

The results of the analysis presented in **Table 5** demonstrate the need for the release of an additional 17,069 acre/ft of water, above the historic 1-in-10 releases, from Lake Istokpoga to meet additional needs for the Indian Prairie Basin during a 1-in-10 drought event. During average rainfall conditions no additional releases from Lake Istokpoga beyond those currently delivered are anticipated. **Table 5** shows the anticipated 1995 to 2020 average increase in demands for the Indian Prairie Basin and the historic mean monthly combined discharge from the S-71, S-72, and S-84 structures. As seen in the table, the mean discharges are greater during each month than the anticipated increase in demands for the average condition. Values in column 5 of this table are all positive suggesting that sufficient water is discharged through the lower three basin structures under the current operational/management guidelines to meet the anticipated monthly increase in demands under average conditions.

Table 6. Budget Demands Based on Capture of Existing Flow, Use of Istokpoga, and Use of Lake Okeechobee during Average Conditions.

Month	Demands & Min. Flow Req. (ac/ft)	Mean Discharge to Lk Okeechobee (S-71,S-72, and S-84)	Min. Flow Req. 40E-22	Deficit (ac/ft)[a]	Additional Supply from Lk Istokpoga (ac/ft)
January	8,727	11,284	220	2,557	0
February	10,374	13,212	650	2,838	0
March	13,153	22,900	800	7,747	0
April	11,450	13,567	540	2,117	0
May	9,147	11,842	440	2,695	0
June	19,674	22,158	6,500	2,484	0
July	18,307	38,050	5,800	19,743	0
August	12,991	49,725	5,500	32,734	0
September	21,256	38,442	6,100	17,186	0
October	22,824	37,608	9,200	14,784	0
November	10,160	22,143	1,600	11,983	0
December	8,028	14,983	360	6,955	0
Total	172,091	295,914	37,710	123,822	0

a. positive values denote no deficit.

Lake Okeechobee Analysis

The analysis of Lake Istokpoga and Indian Prairie Basin indicates that in order to meet the projected demands, the use of water from Lake Okeechobee or other outside sources will be necessary. An evaluation of the use of water from Lake Okeechobee to supply a portion of the projected 2020 demands for the Indian Prairie Basin was made using the South Florida Water Management model (SFWMM). The SFWMM is a regional-scale computer model that simulates the hydrology and the management system of the surface water resources from Lake Okeechobee to Florida Bay. It covers an area of 7,600 square miles using a mesh of 2 mile x 2 mile cells. In addition to accounting for the systems within the model domain, the model includes inflows from the Kissimmee River, discharges and withdrawals from the Lake Istokpoga-Indian Prairie Basin, and runoff and demands in the Caloosahatchee River and St. Lucie canal basins.

The model simulates the major components of the hydrologic cycle in South Florida including rainfall, evapotranspiration, infiltration, overland and ground water flow, canal flow, canal to ground water seepage, levee seepage, and ground water pumping. It incorporates current or proposed water management control structures and current or proposed operational rules. The ability to simulate water shortage policies affecting urban, agricultural, and environmental water uses in South Florida is a major strength of this model.

The SFWMM simulates hydrology on a daily basis using climatic data for the 1965-1995 period which includes many droughts and wet periods. The model has been calibrated and verified using water level and discharge measurements at hundreds of locations distributed throughout the region within the model boundaries. Technical staff of many federal/state/local agencies and public/private interest groups have accepted the SFWMM as the best available tool for analyzing regional-scale structural and/or operational changes to the complex water management system in South Florida.

Projected surface water demands from each of the District's four planning areas as well as consideration of the components identified in the Restudy and minimum level for Lake Okeechobee were incorporated into simulations of the model. As part of these simulations, requests for additional use for the Lake Istokpoga-Indian Prairie Basin were made along with the other components listed above. Results of the SFWMM simulations suggest that an amount of 85,700 ac/ft may be diverted from Lake Okeechobee to the Indian Prairie Basin during a 1-in-10 drought year and still meet the required performance measures for Lake Okeechobee. This amount reflects the total combined amount from the reduction of flows to and backpumping from Lake Okeechobee.

SUMMARY OF SURFACE WATER ANALYSIS

The examination of the surface water resources within the KB Planning Area focused on a determination of the availability of supplies from the Lake Istokpoga-Indian Prairie Basin. This is an area that has historically had water supply issues due to its dependency on Lake Istokpoga for water. Statistical and empirical approaches were taken to evaluate the amount of water currently being released from the basin that might be captured and utilized for future growth. This analysis indicated that supplies from Lake Istokpoga and surface water runoff in the Indian Prairie Basin are insufficient under the current management/operation schedule to meet the projected 2020 1-in-10 drought demands for water.

Using the estimates of available water determined from the analysis, an evaluation of the alternative sources was performed. A water budget model was created to evaluate the use of additional water from Lake Istokpoga in combination with water backpumped from Lake Okeechobee into the basin. The analysis determined that the 2020 1-in-10 drought demands could be met through the combined use of the two sources. The analysis also indicates that, under the designed drought event (1-in-10 drought preceded by average rainfall), pumps G-207 and G-208 are sufficient to meet the 2020 demand needs.

These analysis performed do not address the issue of seasonal or annual drought events greater than the design event. In those instances, the availability of surface water to meet the entire growing season becomes questionable.

SUMMARY OF RESULTS

Based on the results of the analyses, there are several potential water supply problems projected for the 2020 planning horizon that warrant the attention of the water management districts in Central Florida. For Orange and Osceola counties, the analysis performed defines areas where withdrawals place the users at higher risk of contributing to harm to wetland, significant saline water movement and sinkhole formation. The identification of these higher risk areas does not imply that impacts under these criteria will occur, but instead is intended to provide guidance on the possible risks that may result from future ground water withdrawals and to identify where future research efforts should be focused.

The examination of the surface water resources within the KB Planning Area focused on a determination of the availability of supplies from the Lake Istokpoga-Indian Prairie Basin. This is an area that has historically had water supply issues due to its dependency on Lake Istokpoga for water. An analysis performed indicates that current supplies from Lake Istokpoga and surface water runoff in the Indian Prairie Basin are insufficient under the current management/operation schedule to meet the projected 2020 1-in-10 drought demands for water. The analysis further demonstrates that the combined uses of Lake Okeechobee and Lake Istokpoga are available to meet the projected 2020 demands. The use of these sources, however, may require the construction of additional infrastructure to move water to the areas needed.

Resolution of these issues is the basis of developing water source options and recommendations for the advisory committee presented in Chapter 5.